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13. ABSTRACT *(Maximum 200 words)*

Significant progress has been made towards achieving the research objectives in the ar-eas of physical modeling, algorithm development, and experimental evaluation. We have carefully analyzed the physics underlying the information of airborne hyperspectral imagery over the 0.4/ ~ m-2.5ttm spectral range which corresponds to the HYDICE and AVIRIS sen-sors. The new spectral radiance model includes reflected solar and scattered radiation as well as the effects of atmospheric gases and aerosols. We have shown using a statistical analysis of the radiance model that the variation in an object's spectral signature lies in a low-dimensional space. This result is the basis of a new maximum likelihood ATR algorithm that is invariant to illumination and atmospheric conditions. We have demon-strated that the new recognition algorithm significantly outperforms existing algorithms over a range of HYDICE and AVII/IS imagery over a range of conditions. We have also evaluated the use of linear models for representing mid-wave and long-wave infrared spectral reflectance functions.

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1 Objectives

The primary objective of this project is to develop algorithms for the reliable recognition of targets in multispectral infrared images under arbitrary illumination, atmospheric, and thermal conditions. The algorithms will be derived from a detailed physical model for infrared image formation and combine spectral and spatial characteristics of targets and backgrounds. The use of these algorithms to process imagery from airborne platforms will significantly improve battlefield awareness in several areas. Since the new algorithms can exploit arbitrary combinations of spatial and spectral characteristics in unconstrained environments, they will be especially valuable for recognizing partially concealed targets and camouflaged targets as well as distinguishing targets from decoys. Techniques developed in this work can be used to classify and register image areas independent of illumination and atmospheric conditions. The algorithms can also be used for material identification for applications such as determining terrain trafficability.

2 Status of Effort

Significant progress has been made towards achieving the research objectives in the areas of physical modeling, algorithm development, and experimental evaluation. We have carefully analyzed the physics underlying the formation of airborne hyperspectral imagery over the 0.4μm-2.5μm spectral range which corresponds to the HYDICE and AVIRIS sensors. The new spectral radiance model includes reflected solar and scattered radiation as well as the effects of atmospheric gases and aerosols. We have shown using a statistical analysis of the radiance model that the variation in an object's spectral signature lies in a low-dimensional space. This result is the basis of a new maximum likelihood ATR algorithm that is invariant to illumination and atmospheric conditions. We have demonstrated that the new recognition algorithm significantly outperforms existing algorithms over a range of HYDICE and AVIRIS imagery over a range of conditions. We have also evaluated the use of linear models for representing mid-wave and long-wave infrared spectral reflectance functions.

3 Publications

[1] D. Slater and G. Healey, "ATR in Multispectral Imagery using Physics-based Invariant Representations," ATRWG System and Technology Symposium, Redstone Arsenal, AL, October, 1997.

[2] D. Slater and G. Healey, "A Method for Material Classification in AVIRIS Data with Unknown Atmospheric and Geometric Parameters," JPL Airborne Earth Science Workshop, January 1998.

[3] G. Healey and D. Slater, "Exploiting an Atmospheric Model for Automated Invariant Material Classification in Hyperspectral Imagery," SPIE Conference on Algorithms for Multispectral and Hyperspectral Imagery IV, Orlando, April 1998.

[4] D. Slater and G. Healey, "What is the Spectral Dimensionality of Illumination Functions in Outdoor Scenes?" IEEE Conference on Computer Vision and Pattern Recognition, Santa Barbara, June 1998.

[5] G. Healey and L. Benites, "Linear Models for Spectral Reflectance Functions over the Mid-Wave and Long-Wave Infrared," *Journal of the Optical Society of America A*, to appear.

[6] D. Slater and G. Healey, "Analyzing the Spectral Dimensionality of Outdoor Visible and Near-infrared Illumination Functions," Journal of the Optical Society of America A, 15(11), 2913-2920, November 1998.

[7] G. Healey and D. Slater, "Image Understanding Research at UC Irvine: Automated Invariant Recognition in Hyperspectral Imagery," Proceedings of the DARPA Image Understanding Workshop, 631-639, 1998.

[8] B. Thai and G. Healey, "Invariant Subpixel Material Identification in Hyperspectral Imagery," Proceedings of the DARPA Image Understanding Workshop, 809-814, 1998.

[9] D. Slater and G. Healey, "Reflectance Estimation and Material Identification for 3D Objects in Outdoor Hyperspectral Images,"Proceedings of the DARPA Image Understanding Workshop, 815-820, 1998.

[10] B. Thai, G. Healey, and D. Slater, " Invariant Subpixel Material Identification In AVIRIS Imagery," JPL AVIRIS Workshop, February 1999.

[11] B. Thai and G. Healey, "Invariant ATR for Subpixel Targets in Hyperspectral Imagery," ATRWG System and Technology Symposium, Monterey, March, 1999.

[12] D. Slater and G. Healey, "Material Mapping for 3D Objects in Hyperspectral Images," SPIE International Symposium on Aerospace/Defense Sensing Simulation and Controls, Orlando, April 1999.

[13] B. Thai and G. Healey, "Invariant Subpixel Target Identification in Hyperspectral Imagery," SPIE International Symposium on Aerospace/Defense Sensing Simulation and Controls, Orlando, April 1999.

[14] G. Healey and D. Slater, "Invariant Recognition in Hyperspectral Images," Proceedings of IEEE Conference on Computer Vision and Pattern Recognition, Vol. I, 438-443, June 1999.

[15] D. Slater and G. Healey, "A Spectral Change Space Representation for Invariant Material Tracking in Hyperspectral Images," SPIE International Symposium on Optical Science, Engineering, and Instrumentation (SPIE Annual Meeting), Denver, 18-23 July 1999.

[16] P. Suen and G. Healey, "Modeling and Recognizing Hyperspectral Textures Under Unknown Conditions," SPIE International Symposium on Optical Science, Engineering, and Instrumentation (SPIE Annual Meeting), Denver, 18-23 July 1999.

[17] G. Healey and D. Slater, "Models and Methods for Automated Material Identification in Hyperspectral Imagery Acquired Under Unknown Illumination and Atmospheric Conditions," IEEE Transactions on Geoscience and Remote Sensing, 37(6) 2706-2717, November 1999.

[18] P. Suen, G. Healey and D. Slater, "Material Identification over Variation of Scene Conditions and Viewing Geometry," SPIE Volume 4049, Algorithms for Multispectral, Hyperspectral, and Ultraspectral Imagery VI, Orlando, Florida, April 2000.

[19] Z. Pan, G. Healey and D. Slater, "Modeling the Spectral Variability of Ground

Irradiance Functions," SPIE Volume 4049, Algorithms for Multispectral, Hyperspectral, and Ultraspectral Imagery VI, Orlando, Florida, April 2000.

[20] G. Healey and D. Slater, "Lessons Learned: Technology transfer from terrestrial spectroscopy to biomedicine," SPIE Volume 3920, Spectral Imaging: Instrumentation, Applications, and Analysis, San Jose, January, 2000.